Exploitation of AFRC Research

93-94

Agricultural & Food
Research Council

Annual Report

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Biotechnology and Biological Sciences
Research Council (BBSRC)

Contents

To the Chancellor of the Duchy of Lancaster

The Agricultural and Food Research Council, as required by Schedule 1 of the Science and Technology Act, 1965, submits the following Report on its activities during the period from 1 April 1993 to 31 March 1994.

Sir Alistair Grant
Chairman

Professor T L Blundell FRS
Deputy Chairman and Director General

Laid before Parliament pursuant to Schedule 1 of the Science and Technology Act, 1965. 7 December 1994.

Agricultural and Food Research Council

The mission of the Agricultural and Food Research Council is to advance scientific knowledge for agriculture, food and other biology-based industries and for sustainable use of land and biological resources.

This is the last Annual Report of the Agricultural and Food Research Council (AFRC). On 1 April 1994, the AFRC was incorporated, together with biotechnology and biological sciences programmes of the former Science and Engineering Research Council, to form the new Biotechnology and Biological Sciences Research Council (BBSRC).

The AFRC was funded primarily from the Science Budget of the Office of Science and Technology (OST). For some of the research conducted in institutes, it also received commissions from the Ministry of Agriculture, Fisheries and Food (MAFF). In addition the Council received funding from other Government Departments, the EC, and from commercial companies.

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Chairman's Statement

The Agricultural and Food Research Council was incorporated into a new Biotechnology and Biological Sciences Research Council (BBSRC) on 1 April 1994 as foreshadowed in last year's White Paper*. Inevitably, this evolution involved extensive consultation and planning in order to minimise disruption to researchers and to ensure a smooth transition to the new Council. That it was achieved under "business as usual" at AFRC is a tribute to the enormous efforts of the Director General and all of the staff. It is also a reflection of the enthusiastic anticipation of BBSRC which was apparent in both the academic research and the industrial communities served by the new Council. All associated with the Council have been greatly encouraged by the widespread recognition that the integration of research in biology and related areas of chemistry, physics and engineering, within a single Council, will offer exciting new opportunities in science and in innovation and application for industry.

In this, the last Annual Report of the AFRC, we take the opportunity to describe how research during the past year, and earlier, has fulfilled our mission to provide top quality science in the service of agriculture, food and other industries. The mission-orientated ethos of AFRC will be developed further in the new research council, where I am sure the science of the former AFRC will combine with the basic biology and biotechnology of the former Science and Engineering Research Council to make a major contribution to creating wealth and improving the quality of life.

I was delighted to accept the invitation of the Chancellor of the Duchy of Lancaster to be Chairman of the BBSRC. I look forward to working with the new Council and to building upon the proud legacy of the AFRC.

Sir Alistair Grant

December 1994

* *Realising our Potential, A Strategy for Science, Engineering and Technology, May 1993, Cm 2250.*

Membership of Council

as at 31 March 1994

Sir Alistair Grant
Chairman

Professor T L Blundell FRS
Deputy Chairman and Director General

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Chief Scientific Adviser, MAFF

Mr C R Cann
Deputy Secretary, Countryside, Marine Environment and Fisheries, MAFF

Professor E C D Cocking FRS
University of Nottingham

Professor J R Coggins
University of Glasgow

Sir Sam Edwards FRS
University of Cambridge

Mr D F R George OBE
Dyfed Seeds

Mr A B N Gill
Deputy President, NFU

Professor R M Hicks OBE
United Biscuits (UK) Ltd

Professor G Horn FRS
University of Cambridge

Professor W P T James CBE
Rowett Research Institute

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Professor J R Krebs FRS
University of Oxford

Professor C J Leaver FRS
University of Oxford

Professor R M Leech
University of York

Dr T Little
Unilever Research, Colworth Laboratory

Mr K J MacKenzie
Secretary, SOAFD

Mr J L C Provan
Farmer

Mr G T Pryce CBE
Chairman, Horticulture Research International & Solway Foods Ltd

Dr D W F Shannon
Chief Scientist, Agriculture and Horticulture, MAFF

Professor W V Shaw
University of Leicester

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Dr C H McMurray - *DANI*
Mr K C Meldrum - *MAFF*
Professor H J Newby - *ESRC*
Sir Dai Rees FRS - *MRC*
Mr O Rees CB - *Welsh Office*
Sir Mark Richmond FRS - *SERC*
Dr G W Robinson - *DTI*
Professor H Smith FRS - *Royal Society*
Mr D Wilkinson CB - *OST*

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Deputy Chairman and Director General

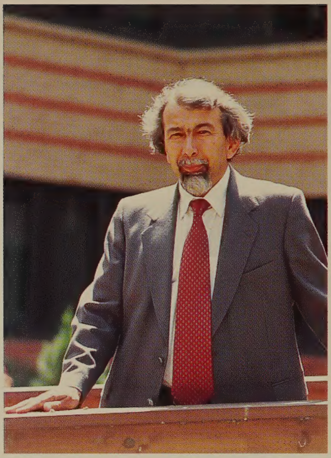
Dr B G Jamieson
Director of Administration

Dr A V Harrison
Head of Policy Division

Mr R J Price
Head of Human Resources

Mr S H Visscher
Chief Finance Officer

Dr J N Wingfield
Head of Science Division



Director General's Review

The last year of operation of the AFRC was undoubtedly as busy and exciting as any of the preceding sixty two in the Council's history and this Report features some of the many scientific achievements.

I was delighted to accept the invitation of the Chancellor of the Duchy of Lancaster to serve as Chief Executive of the new Biotechnology and Biological Sciences Research Council. Inevitably, much time and effort has been spent during the past year in ensuring a smooth transition to the new Council. I am very grateful for the support of all in the research community and in the agricultural, food, chemical, pharmaceutical and other industries who provided advice on how the structures of the new Council might best serve scientific and industrial priorities.

This Report illustrates both the robust state of AFRC science and the positive contribution it has made to industrial innovation. A very good illustration of the feedthrough from basic science to industry is the opening of the new Pharmaceutical Proteins Ltd Laboratories at Roslin (page 5) but there are many others!

Technology Interactions

Shortening the time between research and industrial innovation will be a major objective in the BBSRC and one which will build upon the AFRC's achievements during the past year. We have maintained a strong programme of collaborative work with industry with the primary objective of increasing technology transfer from the science base. During the year, the Council established a sub-committee under the chairmanship of Dr Tom Little, Unilever Research, to evaluate existing schemes for collaboration with industry and to make recommendations for future Council support for such schemes and increased interaction with industry in general.

The committee recommended a new technology interaction policy for BBSRC based on the need to maximise the ability to exchange and exploit ideas, knowledge and technology with industry for the benefit of the UK economy and ultimately for improvement in the quality of life. The committee also strongly endorsed the AFRC's current initiatives for supporting collaborative research with industry. These initiatives are the AFRC's commitment under the Government's LINK scheme, in which AFRC is involved both as a programme sponsor and, through its institutes, as an academic partner; and the AFRC's own Collaboration With Industry Scheme (CWIS) which operates along similar lines.

AFRC is a co-sponsor of 11 of the 36 LINK programmes approved to date.

In addition, a total of 42 projects have been approved under the CWIS programme since its inception in 1992 at a total cost to AFRC of £5.5M.

During 1993-94 AFRC institutes undertook contract research for industry to the value of about £12M. Examples of major industrial funders are:

Agricultural Genetics Company Ltd
British Technology Group
Ciba-Geigy Agrochemicals
Du Pont (UK) Ltd
Germinal Holdings
Intervet plc
Nestec
Pharmaceutical Proteins Ltd
Mallinckrodt Veterinary Ltd
SmithKline Beecham plc
Sigma Tau Pharmaceuticals
Unilever plc
Zeneca plc

We have continued to explore effective ways of communicating the results of AFRC research to a broader public within our industrial user communities. I was delighted to be invited to speak on non-food uses of agriculture at the AGM of the National Farmers' Union, and to give the 1993 Annual Lecture of the Royal Agricultural Society of England. The Council enjoys good working relationships with both the NFU and the RASE - which will continue to be of the utmost importance in the BBSRC. AFRC presentations during the year included the Royal Show, the Grassland and Cereals

AFRC Commitment in LINK programmes

	£K
Control of Plant Metabolism	300
Protein Engineering	830
Eukaryotic Genetic Engineering	500
Molecular Sensors	250
Design of High Speed Machinery	500
Industrial Use of Crops (AFRC - lead sponsor)	1,500
Agro-Food Quality	500
Technologies for Sustainable Farming Systems	450
Biotreatment of Soil and Water	500
Cell Engineering	500
Advanced and Hygienic Food Manufacture	1,000
	6,830

events and Cereals Quality III - a meeting of the Association of Applied Biologists. This approach will be continued in the BBSRC, already plans are in hand for joint initiatives with the Institution of Chemical Engineers, the Institute of Biology and Chemistry Research for Britain aimed at bringing together academic and industrial scientists.

Links with Europe

We have continued to build on our collaborative links with Europe. The AFRC was active in promoting the EC Framework Programme III to its community. A new model of funding for a large scale coordinated project was pursued through the AMICA plant molecular biology project, involving the John Innes Centre. The Council also played a significant role in contributing to policy discussion on the programme lines of the new Framework Programme IV.

The Council worked closely with its counterparts in France (INRA) and The Netherlands (DLO) to further collaboration following on from the last annual review meetings in December 1992.

An active role was played in the annual Tetrapartite meeting, involving research managers in the UK, USA, France and Canada, held in Edinburgh in June 1993. Topics discussed included biodiversity, food safety and food irradiation, non-food crops, sustainable agriculture, bioethics, and access to data.

As well as funding fellowships under the INRA scheme, collaboration was facilitated through the ISIS scheme (International Scientist Interchange Scheme). Funds are provided for travel and subsistence costs to promote international collaboration. A total of 175 visits were funded to a total of £165K, with visits to Eastern Europe targeted as a priority area.

Developing Countries

The Council considered how best to promote its activities in relation to developing countries. A new organisational framework was agreed with the International Agricultural Development Unit, under Professor Jo Anderson, taking the lead. The Unit identifies and facilitates scientific opportunities for research and training with national and international organisations involved in agricultural development. Particular attention is focused on the transfer of expertise and new technologies in soil, crop and animal sciences and on strategic research relevant to potential new markets. The unit will also coordinate bids by British research consortia for project funding in developing countries.

During my recent visit to China, I was very impressed to see how a developing country could be fully involved in the new agricultural biotechnologies.

Public Understanding of Science

The Arthur Andersen review "UK biotech '94 - the way ahead", published in February 1994 predicts strong growth in the UK industry, most particularly in biopharmaceutical companies, who expect sales to increase by over 60%, and in the "Agbio" companies comprising agriculture, horticulture, animal healthcare and food technology where a growth rate of over 250% is predicted over the next three years.

It is widely recognised that public acceptability of the new technologies will be a major factor, and indeed may be a rate limiting step, in their commercial exploitation and appearance in the market place.

The AFRC has already developed a programme on public understanding of biotechnology (page 13). This is focused primarily on the teaching of biology in schools with the long term aim of improving public knowledge of the underpinning science, and on investigating the use of Consensus Conferences to stimulate public debate and understanding of science. Both these approaches, and others to stimulate direct interaction between researchers and the public, will be developed further in the BBSRC.

Tom Blundell FRS
Deputy Chairman and Director General

Parliamentary Select Committees

During the year the Council presented evidence to the following committees:

House of Lords Select Committee on Science and Technology: Sub-Committee II - Regulation of the UK Biotechnology Industry and Global Competitiveness. May 1993.

House of Lords Select Committee on Science and Technology: Inquiry into Setting Priorities for the Science Base. July 1993.

House of Commons Select Committee on Science and Technology: Inquiry into Innovative and Competitive Technology. July 1993.

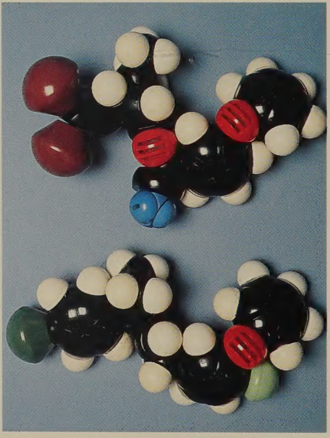
House of Commons Select Committee on Agriculture: Inquiry into the UK Poultry Industry, covering both the Poultry and Egg Sectors. October 1993.

House of Lords Select Committee on the European Communities: Inquiry into Patent Protection for Biotechnological Inventions. November 1993.

Exploitation of AFRC Research

Earlier research, now commercialised

Here we present three examples of research which has been successfully commercialised. In taking examples from chemical, engineering and molecular biological research we illustrate the breadth of AFRC expertise and its industrial relevance.



Research supported by the BTG led to the discovery of photostable pyrethroids, such as deltamethrin (top) which is now an established insecticide with extensive worldwide sales. Subsequent developments include simpler compounds such as "NRDC 199" (bottom), a non-ester pyrethroid with potential for control of some insecticide-resistant insects.

Synthetic pyrethroid insecticides

An understanding of the molecular basis of the natural insecticidal properties of the pyrethrum daisy led chemists at Rothamsted Experimental Station to develop synthetic analogues of the natural active compound, pyrethrin 1. During the late 1960s and early 1970s, several analogues were produced, including resmethrin. Towards the end of this period analogues with improved stability in light and air were also developed, including deltamethrin, one of the most potent insecticides known.

Key characteristics of the synthetic pyrethroids are their high insect specificity and activity, and their outstandingly low mammalian toxicity. Also, unlike DDT and other organochlorine pesticides, synthetic pyrethroids are readily metabolised in the soil to harmless products.

The synthetic pyrethroids were rapidly taken up by industry and have been subsequently used widely in agriculture, forestry, veterinary areas and horticulture. Patent rights on the Rothamsted research were assigned to the National Research Development Corporation, now the British Technology Group Ltd. BTG Ltd continued to support research at Rothamsted on new analogues, including some active against soil-inhabiting pests, and more recently on identification of novel insecticidal compounds from plants.

In 1991, annual value of synthetic pyrethroid sales worldwide was about £1.4 billion at end user prices - approximately half of the sales were based on Rothamsted-discovered compounds.

Grain stripping header

A unique stripper system for combine harvesters strips the grain and heads from the plant stalks *in situ* with little chaff and leaf material. Almost all the rest of the crop is left standing in the field and does not pass through the harvester. As a result, the harvester can be driven at up to double the forward speed of a conventional machine with the same level of loss/no increase in losses.

The comb-like mechanism on which the system is based was designed by engineers at the Silsoe Research Institute, in the form of an alternative header for attachment to conventional combine harvesters. Previous research at the institute with a laboratory stripping rig and trials with an experimental stripping rotor had indicated that workrate might be increased by 60-90% using a stripping head instead of a conventional cutter bar. The unique feature of the stripper is the keyhole-shaped combing elements which give highly efficient stripping, and

Stripped straw in the field after stripper harvesting. The Queen's Award for Technological Achievement 1992 was awarded jointly to Silsoe Research Institute and Shelbourne Reynolds Engineering Ltd for the development of the stripper harvester.

also provide an escape route for stripped stems.

Shelbourne Reynolds Engineering Ltd was granted a commercial licence to manufacture the stripper header in 1987 through the British Technology Group. Since then, stripper harvesters have been operating successfully in many countries including the USA, France, Sweden, Italy, Denmark and Australia. Excellent results have been achieved with wheat, rice, barley, oats, linseed and herbage seed. The key advantages of the stripper header are:

- *Harvesting rates are increased by up to 100%*
- *Performs well in laid crops*
- *Allows farmers to harvest in wetter conditions*
- *Reduces grain losses*
- *Gives good results in "necked" barley*
- *Enables farmers to harvest earlier in the season*
- *Allows farmers to start harvesting earlier in the day and to finish later at night.*

A new licence has been granted to Western Combine Corporation in North America to meet the increasing demand there.

Pharmaceuticals from milk

Advances in embryology and reproductive physiology in the 1980s made it possible for very early embryos to be collected in the laboratory, manipulated and returned to the reproductive tract to continue their development. With the tools of molecular biology, it became possible, in principle, to isolate genes of interest, attach them to regulatory genetic sequences that target gene activity to particular tissues, and insert them into developing embryos. In particular, it appeared possible to effect the production of "foreign" proteins in the milk of animals.

This was the thinking behind research at the Roslin Institute where scientists were the first to demonstrate production of medically important human proteins in the milk of sheep. Initially working on mice, and later sheep, they designed effective gene constructs that allow genes coding for human blood clotting Factor IX and the elastase inhibitor α_1-antitrypsin (which has potential for treating degenerative lung disorders) to be expressed in the mammary tissues of the animals. After demonstrations of the feasibility of directing these genes for protein production in sheep's milk, the independent company Pharmaceutical Proteins Ltd (PPL) was established with venture capital funding, to fund continuation and commercialisation of the results.

Focusing on the gene for α_1-antitrypsin, researchers at Roslin set about improving the yields of protein obtained in transgenic animals. Reverting to the mouse model, they found that yields could be increased 100-fold by including "introns" in their gene constructs. These are sequences of DNA in the gene which do not code for the protein, and which had been generally assumed to be unimportant. In fact, they contain important regulatory sequences that govern the extent of gene expression.

PPL exploited this new discovery by generating transgenic sheep. One ewe carrying the intron-containing gene gave up to 35 grams per litre α_1-antitrypsin in her milk.

PPL reached an agreement with the pharmaceutical company Bayer to develop this technology further. Producing human proteins in this way obviates the need for costly low yield blood fractionation procedures which carry a finite risk of contamination with pathogens.

Professor James Watson (co-discoverer with Francis Crick of the double helical structure of DNA) opens the new laboratories of PPL on the Roslin site.

Exploitation of AFRC Research

Current research - today's technologies

Here we present examples of research that is currently being taken forward through the AFRC's programme of technology interactions, including by partnership with commercial companies. These include progress on animal breeding, health and welfare, and on the development of systems for agricultural sustainability.

Animal breeding, health and welfare

Livestock breeding and production

Basic research in embryology continues to provide a foundation for improved cattle breeding technology, including, for example, techniques for low-cost large scale production of identical embryos. This research is developed in close collaboration with commercial consortia.

Recently, in collaboration with the United States Department of Agriculture and Animal Biotechnology Cambridge (Mastercalf), scientists at Babraham Institute have refined a method for separating X-chromosome- and Y-chromosome-carrying sperm from bulls. The technique is based on flow cytometry and exploits the fact that the X-carrying sperm contain 4% more DNA than those carrying the Y-chromosome. It was used in 1993 to produce the world's first calves of pre-determined sex.

A complementary approach to devise an agglutination test to discriminate between the two types of sperm is being pursued in collaboration with Genus Ltd.

BLUP aids UK beef breeding programmes

Best Linear Unbiased Prediction (BLUP) is a statistical technique which uses records of livestock performance to obtain accurate predictions of the breeding value (genetic merit) of all individual animals of a particular breed.

Scientists at the Roslin Institute have collaborated with the Scottish Agricultural College (SAC) Edinburgh in a programme of the Meat and Livestock Commission to develop BLUP for the UK beef industry so that genetic improvement might be accelerated to produce the type of beef animal required for today's market.

A key feature of BLUP is that it allows genetic and management effects on animal performance to be disentangled. This means that genetic merit can be compared more accurately in individuals from different herds. Another important feature is that relationships between **all** animals are included; this improves the accuracy of assessing breeding value, especially for traits of low heritability. BLUP allows comparison of animals in different years, so that overall genetic progress can be measured. The version developed by Roslin Institute and SAC has novel features which enhance the accuracy; these include the simultaneous processing of information on the variety of traits of interest to beef breeders and also the introduction of maternal effects which are important in the growth and development of beef calves.

BLUP evaluations have been completed for several UK beef breeds.

Neurophysiology, animal behaviour and animal welfare

A better understanding of the neurophysiology which controls the induction of lactation and maternal behaviour in ewes has led to two protocols for providing maternal care for orphan and triplet lambs. These offer farmers a more effective and less labour intensive way of rearing the lambs.

Research at the University of Cambridge and Babraham Institute showed that maternal behaviour and bonding to a particular lamb is induced and stimulated by two main factors: hormonal changes in

British Technology Group (BTG) was responsible for securing patent protection worldwide on the attenuated avian coccidiosis vaccine developed at the Institute for Animal Health. BTG licensed the patents to the animal health and productivity company, Mallinckrodt Veterinary Ltd, which now produces and sells the vaccine PARACOX, for the control of coccidiosis in chickens.

pregnancy and stimulation and dilatation of the cervix and vagina during parturition. The latter operates at least in part by inducing release of the peptide hormone oxytocin within the brain. Oxytocin is the only substance known that can induce maternal behaviour in an animal that has not just given birth. But it is not the only peptide involved – the endorphins, natural opiates produced in the brain, are also important in the process of maternal bonding.

Ewes that have given birth can be induced to act as foster mothers to orphan lambs by a simple manual palpation of the vagina and cervix for two minutes which stimulates the same neurochemical changes that occur at parturition. This technique, which can be effective up to three days after the ewe has given birth, persuades her that she has given birth to another lamb, which she will readily accept. Non-pregnant, barren ewes can be stimulated to lactate in six weeks using intravaginal sponges impregnated with the hormones progesterone and oestradiol. Following manual palpation of the cervix and vagina these ewes will then rear orphan and triplet lambs through to weaning with identical growth rates to normally reared lambs.

Vaccines and diagnostics

Basic research on the biology, chemistry and architecture of the immune system, and on the molecular basis of disease has led to the development of many new and novel methods of disease diagnosis, control and prevention. In cases of exotic diseases, the development of diagnostic kits requires disease containment facilities of a high order and the products are distributed by international aid agencies. In other cases, research has been pursued in close collaboration with the pharmaceutical and livestock industries. Some examples of products are:

- *vaccines against the exotic diseases of rinderpest and capripox; the cattle diseases of bovine virus diarrhoea, and bovine respiratory disease; swine dysentery; the poultry diseases of avian coccidiosis and turkey rhinotracheitis;*
- *immuno-diagnostic kits for the exotic diseases of rinderpest, bluetongue, African horse sickness, African swine fever and foot-and-mouth disease; and for* Salmonella enteritidis *in poultry, and bovine diarrhoea;*
- *nucleic acid probes are being tested as diagnostics for several bacterial infections.*

New vaccine against calf pneumonia

Respiratory syncytial (RS) virus is a major cause of calf pneumonia, estimated to cost UK farmers £50M a year. Research at the Institute for Animal Health has led to a powerful new vaccine - Torvac RSV - marketed by C-Vet Veterinary Products.

The new vaccine is based on cells that have been persistently infected with the virus. These are inactivated leaving the protective virus antigen in the cell membrane. The vaccine's unique design elicits a complete and rapid response by the animal's immune system, protecting the calf within eight weeks and significantly reducing its period of susceptibility. This results from the new vaccine's ability to induce effective immunisation in animals with pre-existing maternal antibodies and is a first amongst RS vaccines.

In field trials, mortality in vaccinated calves decreased five-fold and the number of animals requiring subsequent antibiotic treatment was halved. Compared with other "pneumonia" vaccines the incidence of respiratory syncytial virus was more than halved in calves treated with Torvac RSV.

Recombinant vaccines against parasitic nematodes

Many strains of parasitic worm that infest the gastro-intestinal tract of sheep are now resistant to nematicides; and conventional vaccines based on live, attenuated worms are ineffective. Research at the Babraham Institute on the biology of the sheep stomach worm *Haemonchus contortus* identified a protein which is crucially important to the worm. This protein, H11, is at the surface of the parasite's intestine where it is exposed to host blood. It was first revealed from electron microscopy of the gut of *Haemonchus*. The protein was purified from the parasite. When injected into sheep the H11 protein induced the production of antibodies which were shown to protect against infestation by *H. contortus*. H11 has now been fully characterised. Its gene has been cloned and transferred into microorganisms and eukaryotic cells by genetic engineering, ready for large scale production of the protein.

This work is carried out in collaboration with Mallinckrodt Veterinary Ltd. It represents a new approach to vaccination against parasitic worms and should find applications in other species viz. cattle and goats, as well as against human pathogens such as hookworms which infest about 750 million people worldwide.

Technologies for sustainable agriculture

UK agriculture must be profitable and internationally competitive. It must also be environmentally sustainable. Among the multidisciplinary research deployed to direct the development of such systems, are investigations into agricultural diversification into non-food crops, the use of biological and integrated pest control to reduce reliance on chemical pesticides, and the development of crop management systems that optimise the utilisation of agrochemicals and so reduce input costs.

Low Input Systems

The "Less Intensive Farming and Environment" (LIFE) Project is part of a European network of studies on integrated farming systems. Data from Long Ashton Research Station, collected over the past five years, show how profitable quality crop production may be achieved with reduced use of fertilisers and pesticides. Two commercial farms are being used in pilot studies funded by the CEC to demonstrate the technologies to farmers. The systems employed are based on: crop rotations dominated by autumn-sown crops; the use where possible of crop cultivars resistant to diseases and pests; non-inversion tillage for incorporation of crop residues; sparing use of agrochemicals in response to need, with selective pesticides applied wherever possible; and management of field margins to enhance floral and faunal diversity.

At Silsoe Research Institute, engineers have designed a novel "patch spraying" system in which herbicide applications may be targeted to areas where weeds are a problem. This is one example of "precision agriculture" in which field operations can be targeted to meet local requirements, thus avoiding the need for "blanket" or overall application of the full dose of agrochemicals.

A prototype patch sprayer has been developed at Silsoe. It is controlled by two systems: an in-cab personal computer which displays a field treatment map, monitors sprayer position and sets the dose rates to be applied to mapped areas; and an on-board computer-based control system which sets the speeds of the metering pumps, controls the feed section solenoids and is capable of monitoring the in-field performance of all the sprayer control functions for subsequent replay and analysis.

Nematodes (Steinernema feltiae) *emerging from parasitised vine weevil larva.*

Another approach to enhanced environmental protection is the design of more efficient and safer systems for applying agrochemicals. Fundamental studies on fluid dynamics are helping engineers to design improved sprayers. Spray drift from the nozzles on boom sprayers is one problem which is being tackled using mathematical modelling and sophisticated wind tunnel tests. Some of this research is conducted in collaboration with Biologische Bundesanstalt für Land – und Forstwirtschaft, Germany.

Environmental award for bio-control products

Nematode worms which parasitise and kill insect pests are now commercially available as bio-control agents for the glasshouse and mushroom industries. The products are marketed by the MicroBio Division of Agricultural Genetics Company (AGC). They were developed from research at Horticulture Research International funded by the Ministry of Agriculture, Fisheries and Food, AFRC and AGC. For this work, HRI and AGC were granted the 1993 Queen's Award for Environmental Achievement. This Award is made only for products, technology or processes which have achieved commercial success, represent a significant degree of innovation, and offer major benefits in environmental terms.

The nematodes used are *Steinernema feltiae* and *Heterorhabditis megidis* which occur naturally in soils throughout the UK. They are capable of invading a wide range of insect larvae in which they release a lethal dose of pathogenic bacteria (*Xenorhabdus* spp). The nematodes reproduce in the dead insect releasing a new generation of worms that seek out and invade further insects. Trials at HRI show that preventative treatment of nursery stock, seedlings, pot plants and propagated material can protect against glasshouse sciarid flies, obviating the need for chemical insecticides.

Silsoe engineers have developed a novel machine for extracting fibre from linseed straw.

Linseed fibre - full scale extractor developed

Each year, about 300,000 tonnes of linseed straw are generated as a by-product of seed production in the UK. A £1.1M project under the LINK Programme on "Crops for Industrial Use" is exploring the extraction and use of fibre from this straw.

The project, which is being coordinated by Silsoe Research Institute, is based around the use of a novel machine to extract the fibre, developed previously at the Institute under funding from the Ministry of Agriculture, Fisheries and Food. Several modifications have been made to the laboratory-scale machine, resulting in significant improvements in both the throughput of straw and the cleanliness of the fibre produced. A full scale fibre extraction machine is planned for operation in Autumn 1994.

Flax for high quality fibre to be made into linen differs only from linseed in being taller and having finer fibre in its straw. Whilst flax needs specialist pulling machines to harvest it, linseed can be harvested with a combine and the straw baled. The extraction machine will take in bales of straw and produce bales of fibre.

A length of knitted tubing is superimposed on a sample of the straw; the knitted fabric was made from yarn composed of 50% seed-flax fibre and 50% cotton.

Agricultural merchant, Robin Appel Ltd, one of the industrial partners in the Fibrelin project, is shortly to begin operating new decorticators in the UK. A network of regional processing plants is planned for the next few years.

Among the potential uses of linseed fibre are those in the textile, geotextile, agrotextile, oil absorption paper and automotive industries.

Exploitation of AFRC Research

New research for tomorrow's technologies

Here we outline how advances in genome analysis and manipulation, image analysis and enzyme science will offer new opportunities for innovation in a wide range of industries.

Genome analysis and gene transfer

Our understanding of the organisation and function of the genetic material of plants, animals and microorganisms continues to advance rapidly as the techniques of molecular and cell biology yield new experimental tools and methodologies. We are gaining new insights, at the most basic level, about how organisms behave as they do, and we are beginning to identify and isolate genes that code for industrially useful traits. New technologies for modifying and transferring these genes offer unprecedented opportunities for the directed improvement of crops and livestock, as well as for the development of plant, animal and microbial systems for producing high value compounds such as therapeutics and fine chemicals. The AFRC supports strong national and international programmes on genome mapping in the pig (PiGMaP), cow (BoVMaP), chicken, cereals and *Arabidopsis*. We have recently launched a £2M coordinated programme on "Plant and Genome Analysis" with applications invited from universities, AFRC institutes, Government Research Establishments and Agencies, and institutes of other Research Councils.

Genomic similarities of wheat, rice, maize and other grasses

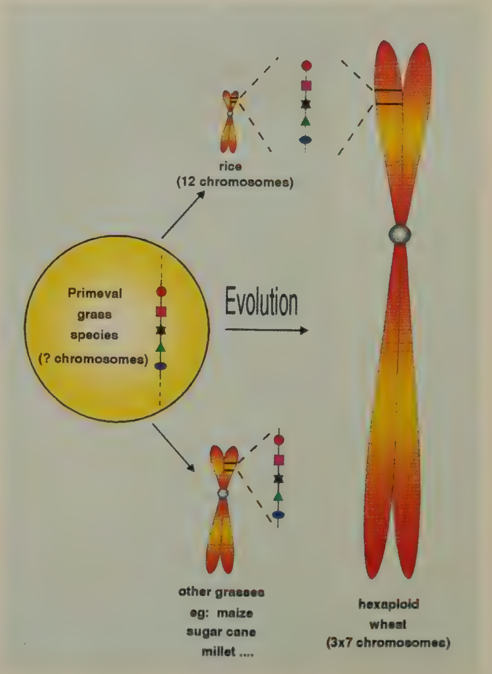
Wheat and rice evolved separately from a common ancestor about 60 million years ago; and today, the genome of wheat is about 40 times the size of that of rice. However, a study between scientists at the Cambridge Laboratory (John Innes Centre) and the National Institute of Agrobiological Research in Japan shows that the genes themselves and their order in the chromosomes are virtually identical in wheat and rice.

What this means for the plant breeder is that information about the rice genome can be used to assist wheat genetics and *vice versa*. The JIC group is integrating the maps of sorghum, rye, barley, maize and other grasses into a hypothetical "primeval grass genome". This will have major implications for cereal breeding research and it overcomes a major obstacle in the large amount of highly repetitive DNA sequences which hinders detailed molecular analysis, including gene isolation, in wheat.

Genetically transformed grasses

A method for introducing genes into forage grass was reported for the first time in the UK by scientists at the Institute of Grassland and Environmental Research. It is based on incubating protoplasts (plant cells in which the outer cell wall has been removed) in a solution of DNA and polyethylene glycol, the latter facilitates entry of the DNA into the protoplasts. Key to the success of this approach has been the development of a method for regenerating grass plants from single transformed protoplasts.

So far, the transformation technique has been used to co-introduce a reporter gene which allows gene expression to be monitored and a selectable gene which allows the plant to grow in the presence of the antibiotic hygromycin. This allows easy selection of those plantlets that have taken up the new genes. The next stage



The comparison of the gene order within cereal chromosomes enables the gene order within the chromosomes of the primeval grass to be reconstructed. The mapping of important traits can then be compared across cereals and the information used to isolate the genes controlling these traits.

will be to co-transform cells with the selectable and other, economically important genes.

Potential agricultural uses of transgenic grasses include making improvements in both nutritional quality and plant development. Introducing stress or disease resistance genes from other species should increase health and persistence, whilst modifying plant metabolism should increase digestibility, enrich protein composition and improve silage fermentation. Potential environmental and amenity applications include introducing resistance to heavy metals and other soil pollutants and improving the appearance, growth and wear characteristics.

Gene transfer in wheat

Conventional techniques of gene transfer have proved largely unsuccessful with wheat and strategies for its genetic manipulation have lagged behind those for maize and rice. Two things have been lacking: an effective DNA delivery system and a method for ensuring tissue regeneration.

Scientists at the Institute of Arable Crops Research, Rothamsted Experimental Station have overcome these problems by using a helium particle gun to fire gold pellets coated in DNA direct into highly regenerable cultures of immature inflorescence and scutellum tissue. They have successfully introduced marker genes into tritordeum (a cross between wild barley and durum wheat), and into model wheat cultivars.

This research is being taken forward in collaboration with MAFF and Zeneca Seeds. An early target will be the directed introduction of genes for storage proteins which improve the processing characteristics of the grain.

First germline transgenic chickens

Gene transfer into poultry is difficult because the fertilised egg is inaccessible in the oviduct for the first twenty four hours. By this time, embryonic development has advanced to the 60,000 cell stage, far too late for any injection of DNA to be attempted.

A new embryo culture system, developed by scientists at the Roslin Institute, allows gene transfer into isolated newly fertilised egg yolks. The DNA is injected into the germinal disc of eggs that have been transferred from the oviducts of laying hens into host shells. The injection takes place before the first cleavage division. The embryos are cultured in the host shells where they develop normally.

Successful transfer of a reporter gene, i.e. one that is easily identifiable, has been demonstrated. A line of transgenic chickens has now been bred from a transgenic cockerel showing that the transferred gene is stable and is inherited normally.

This technology has potential for the production of therapeutics and other high value compounds from the eggs of genetically modified chickens; the development of new research tools to investigate mechanisms that control embryo development; and longer-term, the targeted genetic improvement of poultry, for example, by introduction of genes which confer resistance to disease.

Transgenic cockerel and chicks.

Testing a remotely operated vehicle for monitoring fish in large marine cages.

Image processing for marine aquaculture

Expansion of marine fish farming in the UK will inevitably involve greater use of more exposed offshore locations. It has been estimated that by the year 2000 offshore installations will have increased from the present level of about 5% of all fish farms to nearer 20%. One operational problem for fish farms in general, and particularly for deep water farms, is that of monitoring the health, welfare and performance of the fish. For example, although automatic feeding systems can be incorporated into the cages, there is currently no way of matching feed availability direct to fish consumption and growth rates without manual intervention. It is estimated that the Scottish salmon industry might lose up to £4M worth of wasted feed a year under current practices.

A project under the AFRC's Collaboration With Industry Scheme has brought together research scientists, a fish farmer, feed supplier and a marine engineering consultant to develop a monitoring system for marine aquaculture based on image processing. The research partners are Silsoe Research Institute and the University of Stirling Institute of Aquaculture.

The principal scientific challenges have been in the acquisition of video images and their automatic analysis. Existing technology has proved difficult to apply to natural objects of different size and shape in an unstructured and uncontrollable environment. Stereo image analysis software has been developed to locate upper and lower boundaries of imaged fish so that these features may be used to measure 3D coordinates of points on the fish. This enables information on the dimensions of individual fish to be extracted.

A trial system is now under test. A configuration has been determined for two video cameras which are used to produce stereo images of the fish. The cameras are mounted one above the other on a remotely operated vehicle which can be manoeuvred to any point within a sea cage.

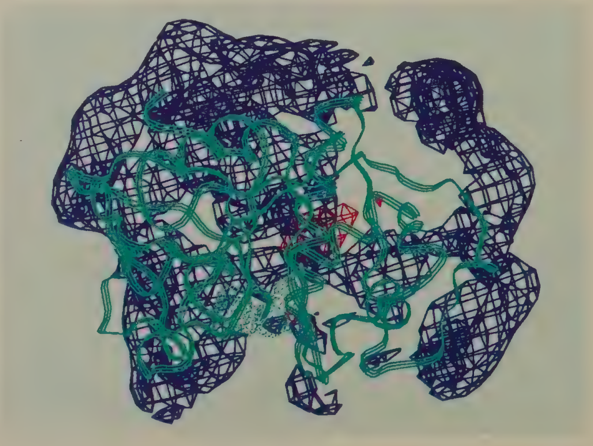
Enzyme Science

Knowledge of the synthesis, folding, structure and function of proteins provides many opportunities for industrial exploitation - for example, in the design of novel drugs or pesticides or in the enhancement of food quality.

One important area is the use of protein engineering to develop novel and improved enzymes for use in industry. Examples include a linked research project between scientists at the Babraham Institute and the University of Newcastle-upon-Tyne, to modulate the activity of microbial cellulases and hemicellulases to widen their usefulness in the pulp and paper industry. Recombinant DNA technology, involving the expression of microbial enzymes in the bacterium *Escherichia coli*, is providing opportunities for establishing how the detailed structure of different enzymes of this type is related to their specificity and catalytic function.

At the Institute of Food Research, scientists have examined the mechanism of action of cysteine proteases as part of a programme to improve the efficiency of the enzymes and to broaden their industrial usefulness, for example, by modifying the enzymes to operate at optimum efficiency at lower pH values - a development that would allow industry to utilise the enzymes in "cleaner" operating conditions which are hostile to microorganisms.

Designing changes in enzymes to allow them to work in industrial environments that are very different from biological environments requires knowledge of the structures essential for catalytic activity. At the IFR, investigations into the electro-static fields of enzymes are providing information about which amino acid residues in the vicinity of the active site of cysteine proteases influence catalytic rate.



The electrostatic field of caricain - an enzyme that uses a cysteine-histidine ion pair to catalyse proteolysis. Correlations can be made between the ionisation of individual amino acids and the rate of enzyme activity.

Public Understanding of Science

The AFRC has continued to expand its programme of publications, exhibitions and events designed to promote public appreciation and understanding of the Council's activities and achievements. Plans for the UK's first Consensus Conference, on Plant Biotechnology, have been developed in collaboration with the Science Museum which has been commissioned to undertake the Conference. This has involved discussions with representatives of Danish and Dutch organisations which have experience of this style of public debate. The UK Conference will take place in November 1994.

Teachers getting to grips with DNA technology designed for use in the classroom. This practical workshop was sponsored by the AFRC and organised by SAPS (Science and Plants for Schools).

The AFRC has continued to focus on schools' communication through increased liaison with teachers and organisations involved in science education. A priority has been to identify and develop ways in which the AFRC might support the teaching of biology and related sciences in schools.

During 1993-94, AFRC's schools'-directed activities have included two competitions for students, one for secondary school students and one for the primary school age group; a feature article on AFRC research on non-food uses of agriculture, in the GCSE science review "Catalyst"; sponsorship of teacher workshops on DNA technology, run by Science and Plants for Schools (SAPS); a schools' conference in conjunction with The Natural History Museum; and new AFRC publications including a sixth form study guide on the nitrogen cycle.

The AFRC participated in the annual meeting of the British Association for the Advancement of Science at the University of Keele in August/September 1993, and in the highly successful first national week of Science, Engineering and Technology (Set7) in March 1994.

In addition to the initiatives which are coordinated by Central Office, there are many which are organised at institutes and universities. Stimulating the research community to participate fully in programmes to improve understanding of science among the public will be a major objective of the Biotechnology and Biological Sciences Research Council.

Members of the public watch a video presentation on how studies on the neurophysiological basis of animal behaviour might be used to identify ways of improving the welfare of livestock – part of the AFRC's display at the 1993 Royal Show.

Financial and Other Reports

Financial Statement

For the financial year ending 31 March 1994, the total income of the Council and Council owned institutes was £156.2M less total recurrent expenditure of £156.6M giving rise to a net operating deficit for the year of £0.4M.

Income was derived from the following sources:

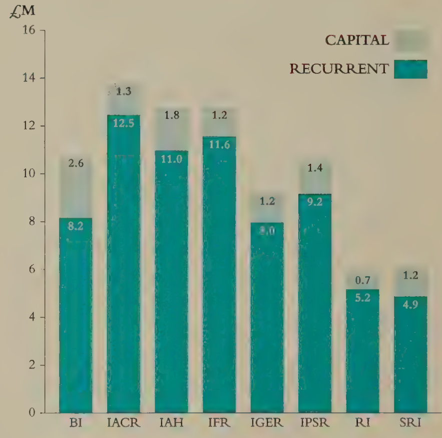
Science Budget grant-in-aid from the Office of Science and Technology was £109.4M and commissioned research from the Ministry of Agriculture, Fisheries and Food amounted to £36.0M.

This major funding was augmented by further Council income totalling £10.8M being mainly contract and other income from industry and Government organisations. The balance came from miscellaneous sales.

In addition to this income received by the Council, grant-aided institutes received outside funding estimated at £14.6M from contracts and other agreements with industry, Government Departments, EC, Foundations and Trusts, etc.

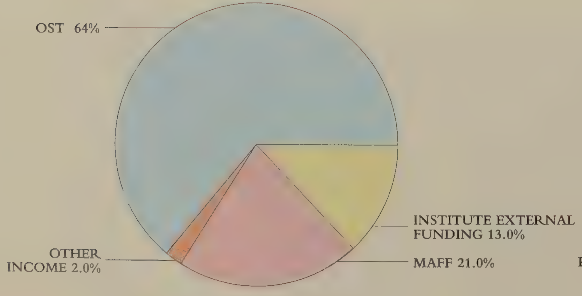
At the year end, the Council owned total assets less current liabilities of £122.7M, an increase of £0.6M over the previous year. This principally represents capital investment in scientific buildings and equipment.

Net Cash Grants to Council and Grant-aided Institutes (£M) 1993/94

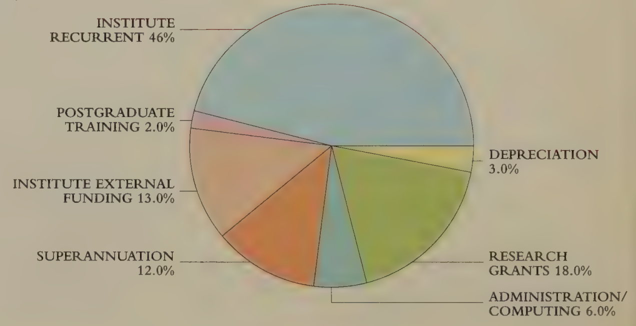


(see Acronyms, back cover)

Total AFRC Income for 1993/94 including External Funding of Grant Aided Institutes (£170.8M)



Total AFRC Expenditure for 1993/94 including External Funding (£171.2M)



Summary of Income and Expenditure of the Council for Year Ended 31 March 1994

	Year Ended 31 March 1994 £000	1994 £000
INCOME		
OST Grant-in-Aid	109,356	
MAFF Commissions	35,980	
Council institutes and units	9,112	
Capital receipts/other income	1,770	
TOTAL INCOME		156,218
EXPENDITURE		
Recurrent Expenditure		
Council and Grant-aided institutes	85,187	
Research Grants to HEIs	31,591	
Postgraduate Training Awards	3,905	
Administrative, Central Computing and Miscellaneous Costs	9,552	
Depreciation	5,358	
Superannuation and Staff Restructuring Costs (Net)	20,000	
Transfers to/from reserves	1,029	
TOTAL RECURRENT EXPENDITURE		156,622
NET OPERATING SURPLUS/(DEFICIT)		(404)
RETAINED SURPLUS BROUGHT FORWARD		3,492
RETAINED SURPLUS CARRIED FORWARD		3,088

Subject to Audit

Agricultural and Food Research Council Balance Sheet as at 31 March 1994

	31 March 1994 £000	1 April 1993 £000
FIXED ASSETS		
Tangible Assets	119,010	118,451
CURRENT ASSETS		
Stocks	734	718
Debtors	6,253	5,720
Cash at bank and in hand	2,925	1,759
Less Creditors falling due within one year	(6,223)	(4,556)
NET CURRENT ASSETS	3,689	3,641
TOTAL ASSETS (LESS CURRENT LIABILITIES)	122,699	122,092
FINANCED BY:		
Accumulated Income and Expenditure Account	3,088	3,492
Provision for Liabilities & Charges	130	130
Deferred Capital Grants	52,041	49,639
Revaluation and Other Reserves	67,440	68,831
TOTAL CAPITAL RESERVES	122,699	122,092

Subject to Audit

Staff Facts

On 31 March 1994, 2891 staff were employed on permanent appointments in the AFRC institutes and Central Office; 105 posts were vacant. Of the permanent staff, 1365 were in the Science Group, of whom 95% were at graduate or equivalent levels. A further 825 members of staff, mainly scientists, held short-term appointments funded either by the AFRC directly (349) or by industry and other external sources (476).

Honours and Awards

The following awards were announced

Birthday Honours 1993

CBE: *Professor H Smith FRS*, Royal Society Assessor, AFRC Council

OBE: *Professor G J Leigh*, Deputy Head, John Innes Centre, Nitrogen Fixation Laboratory

New Year Honours 1994

KB: *Professor C R W Spedding CBE*, Scientific Consultant, AFRC Strategy Board

CBE: *Mr G T Pryce*, AFRC Council
Professor J L Stoddart, former Director, Institute of Grassland and Environmental Research

MBE: *Mr P W Clarke*, Silsoe Research Institute.

Other Distinctions

Professor T L Blundell FRS was awarded an Honorary Fellowship of the Royal Agricultural Society of England. Professor Blundell gave the 1993 RASE Annual Lecture.

Dr M Elliott FRS of the Institute of Arable Crops Research was awarded the 1993 Environment Medal of the Society of Chemical Industry for his pioneering work on the discovery and development of synthetic pyrethroid insecticides.

Dr G R Fenwick of the Institute of Food Research won the Royal Agricultural Society of England's Research Medal for 1993, in recognition of his work on the chemistry of biologically active food components.

Professor (now Sir) David Hopwood FRS of the John Innes Centre was awarded the 1993 Chiron Corporation Biotechnology Research Award (formerly the Cetus Award) for his outstanding contributions to the molecular genetics of *Streptomyces*.

Dr L Stephens of the Babraham Institute was awarded the Biochemical Society Colworth Medal. The medal is awarded to the most distinguished British biochemist under 35.

Professor J L Stoddart was elected to Fellowship of Royal Agricultural Societies (FRAgS) in acknowledgement of his "outstanding personal achievements and record of service to the agricultural industry".

Individual Merit Promotions

The following members of staff were awarded Individual Merit Promotion with effect from 1 July 1993:

Grade 5

Dr R F Irvine, Babraham Institute

Professor J A Pickett, Institute of Arable Crops Research

Grade 6

Dr K M Kendrick, Babraham Institute

Dr R N Perry, Institute of Arable Crops Research

Dr A M Smith, John Innes Centre

Dr J R Stanley, John Innes Centre

Senior Staff Changes

Babraham Institute

Dr R G Dyer was appointed Director with effect from 1 February 1994.

Institute of Arable Crops Research

Professor B J Miflin was appointed Director with effect from 1 January 1994, following the retirement of Professor T Lewis CBE.

Institute of Food Research

Professor A D B Malcolm was appointed Director, following the retirement of Professor D L Georgala CBE in January 1994.

Professor B E B Moseley, Head of Reading Laboratory, retired in February 1994.

Institute of Grassland and Environmental Research

Professor C J Pollock was appointed Director, following the retirement of Professor J L Stoddart in October 1993.

Roslin Institute

Professor G Bulfield was appointed Director with effect from 17 June 1993.

Council Committees

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Deputy Chairman and Director General, AFRC

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(Deputy Chairman) Acting Director of Science

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University of Durham

Professor F J Bourne
Director of Animal Health

Professor G Bulfield
Director, Roslin Institute

Professor R Clift OBE
Chairman, Engineering Research Board

Professor E C D Cocking FRS
Chairman, AFRC Plants and Environment Research Committee

Dr R G Dyer
Director, Babraham Institute

Professor R B Flavell
Director, John Innes Centre

Professor R M Hicks OBE
Chairman, AFRC Food Research Committee

Dr B G Jamieson
Director of Administration, AFRC

Professor J R Krebs FRS
Chairman, AFRC Animals Research Committee

Professor B J Legg
Director of Engineering Research

Professor A D B Malcolm
Director of Food Research

Professor B J Miflin
Director of Arable Crops Research

Professor C J Pollock
Director of Grassland and Environmental Research

Sir Colin Spedding CBE
President, Institute of Biology

Assessor

Mr K Moore
Scottish Office Agriculture and Fisheries Department

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University of Durham

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President, Institute of Biology

Dr J N Wingfield
Head of Science Division, AFRC Central Office

Secretary

Dr C M Miles
AFRC Central Office

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Director of Administration, AFRC

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Mr D J Christie
Scottish Office Agriculture and Fisheries Department

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John Innes Centre

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Mr T G Heller
Secretary, Horticulture Research International

Mr T W Marshall
Secretary, Institute for Animal Health

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Head of Administration, John Innes Centre

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Head of Human Resources, AFRC

Mr P Shaw MBE
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Mr P Swinburne
Secretary, Institute of Grassland and Environmental Research

Mr D Temperley
Secretary, Silsoe Research Institute

Mr S H Visscher
Chief Finance Officer, AFRC

Professor R J Wilkins
Institute of Grassland and Environmental Research

Mr J W Withers
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Dyfed Seeds

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President, Country Landowners Association

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Chief Finance Officer, AFRC

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University of Cambridge

Mr G Harrington OBE
Meat and Livestock Commission

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Director, Hannah Research Institute

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Director, Institute of Grassland and Environmental Research

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University of Stirling

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MRC Clinical Research Centre

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University of Sussex

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Assessor

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University of Leeds

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Director, Institute of Food Research

Professor A A Jackson
University of Southampton

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Dr G Sarna
Medical Research Council

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Director, Macaulay Land Use Research Institute

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University of the West of England

Dr E M H Wellington
University of Warwick

Acronymns

AFRC	Agricultural and Food Research Council
AGC	Agricultural Genetics Company
AMICA	Advanced Molecular Initiative In Community Agriculture
BBSRC	Biotechnology and Biological Sciences Research Council
BI	Babraham Institute
BLUP	Best Linear Unbiased Prediction
BTG	British Technology Group
CEC	Commission of the European Communities
CWIS	Collaboration With Industry Scheme
DANI	Department of Agriculture for Northern Ireland
DLO	Dienst Landboukundig Onderzoek
DNA	Deoxyribonucleic acid
DTI	Department of Trade and Industry
EC	European Community
ESRC	Economic and Social Research Council
HEI	Higher Education Institution
HRI	Horticulture Research International
IACR	Institute of Arable Crops Research
IAH	Institute for Animal Health
IAPGR	Institute of Animal Physiology and Genetics Research
IFR	Institute of Food Research
IGER	Institute of Grassland and Environmental Research
INRA	Institut National de la Recherche Agronomique
IPSR	Institute of Plant Science Research
JIC	John Innes Centre
MAFF	Ministry of Agriculture, Fisheries and Food
MRC	Medical Research Council
NERC	Natural Environment Research Council
NFU	National Farmers' Union
OST	Office of Science and Technology
PPL	Pharmaceutical Proteins Ltd
RASE	Royal Agricultural Society of England
RI	Roslin Institute
SAC	Scottish Agricultural College
SAPS	Science and Plants for Schools
SERC	Science and Engineering Research Council
SOAFD	Scottish Office Agriculture and Fisheries Department
SRI	Silsoe Research Institute